

IRON-BASED CASTING ALLOY AND PROCESS FOR MAKING SAME

Technical Field

5 This invention relates to an improved iron-based casting alloy having improved combinations of toughness, abrasion resistance and corrosion resistance, and the invention also relates to a process for making the alloy.

Background Art

10 There are many applications for which it is desirable to have iron-based alloys that are castable and have improved combinations of toughness, abrasion resistance and corrosion resistance. For example, the paper making industry casts refiner plate alloys which
15 can advantageously increase production at faster speeds. However, at these faster speeds, the cast refiner plates wear faster and are more susceptible to brittle fracture.

20 Cast alloys of iron, chromium, vanadium, niobium, and tungsten have previously been studied by A. Sawamoto et al. as set forth in the Transactions of American Foundrymen's Society, 1986, pages 403-416. While this experimental work studied these alloy systems, the investigations did not optimize the
25 microstructure to provide tougher, more wear and corrosion resistant alloys.

Disclosure Of The Invention

One object of the present invention is to provide an improved iron-based casting alloy having improved combinations of toughness, abrasion resistance
5 and corrosion resistance.

In carrying out the above object, the casting alloy of the invention includes an iron matrix having primary carbides (MC) selected from vanadium carbides, niobium carbides, titanium carbides, and combinations of
10 these carbides with substantially no eutectic MC carbides. The alloy also includes eutectic chromium carbides (M_7C_3) with substantially no primary chromium carbides.

The alloy may also include proeutectic austenite that forms before eutectic austenite that forms with the eutectic chromium carbide.
15

Another object of the present invention is to provide an improved process for making an iron-based castable alloy having improved combinations of toughness, abrasion resistance and corrosion resistance.
20

In carrying out the immediately preceding object, the process for making the casting alloy is performed by precipitating in an iron matrix primary carbides (MC) of vanadium carbides, niobium carbides, titanium carbides, or combinations thereof, and by
25 forming eutectic chromium carbides (M_7C_3) and eutectic austenite without forming any substantial amount of primary chromium carbides.

It is also possible for the process to be performed by precipitating proeutectic austenite before forming the eutectic chromium carbides and eutectic austenite.

5 The objects, features, and advantages of the present invention are readily apparent from the following detailed description of the best modes for carrying out the invention when considered with the accompanying drawings.

10 **Brief Description Of The Drawings**

FIGURE 1 is a graphical representation of the iron-carbon-chromium phase diagram shown by solid line representation and the iron-carbon-M phase diagram by dotted line representation with M metal being niobium, vanadium, or titanium.

FIGURE 2 shows a microstructure of one alloy according to the invention and made by the process of the invention.

20 FIGURE 3 shows a microstructure of another alloy according to the invention and made by the process of the invention.

FIGURE 4 shows a microstructure of a further alloy according to the invention and made by the process of the invention.

25 FIGURE 5 shows a microstructure of a still further alloy according to the invention and made by the process of the invention.

Best Modes For Carrying Out The Invention

With reference to Figure 1, this schematic phase diagram shows the eutectic 10 of the iron-carbon-chromium alloy systems and also shows the eutectic 12 of the iron-carbon-M alloy systems. The alloying component M utilized in accordance with this invention is vanadium, niobium, titanium, or combinations of these elements.

The iron-chromium system has a primary carbide liquidus 14 between the two phase region of liquid and liquid and primary chromium carbide. In addition, this iron-carbon-chromium system has an austenite liquidus 16 between the liquid phase and the two phase region of liquid and proeutectic austenite. Furthermore, the iron-carbon-chromium system has a phase transformation 18 at its eutectic 10, below which any remaining liquid entirely solidifies by eutectic transformation as eutectic chromium carbide and eutectic austenite.

With continuing reference to Figure 1, the iron-carbon-M system has a primary carbide liquidus 20 between the liquid phase and the two phase region of liquid and primary carbides of vanadium, niobium, titanium, and combinations of these carbides. In addition, this system has an austenite liquidus 22 between the liquid phase and the two phase region of liquid and proeutectic austenite. Furthermore, below an isothermal phase transformation 24 at the eutectic 12, the remaining liquid solidifies by eutectic transformation as eutectic carbide and eutectic austenite.

It will be noted in Figure 1 that, in accordance with the present invention, the eutectic 12 of the iron-carbon-M system is located below the hypoeutectic austenite liquidus 16 of the iron-carbon-chromium system such that there is no formation of eutectic carbides of vanadium, niobium, or titanium. Any such eutectic carbides of vanadium, niobium, or titanium would decrease the bulk hardness of the alloy because substantially more eutectic austenite and less eutectic carbides form in the iron-carbon-M system than in the iron-carbon-chromium system.

With continuing reference to Figure 1, in one practice of the invention, the initial transformation from the liquid phase begins at 26s and first passes through the primary carbide liquidus 20 of the iron-carbon-M system to form primary carbides that may be vanadium carbides, niobium carbides, titanium carbides, or combinations of these carbides, but never reaches the eutectic 12 such that there are substantially no eutectic carbides of this system. In addition, the transformation continues until reaching the eutectic 10 of the iron-carbon-chromium system as identified by 26f at which point eutectic chromium carbides (M_7C_3) form with eutectic austenite but with substantially no proeutectic chromium carbides. Any such proeutectic chromium carbides would form large rod-like particles that significantly reduce toughness and thus embrittle the alloy.

In another practice of the invention, but with a relatively lesser amount of carbon, the same transformation takes place as described above starting at 28s at the hypereutectic primary carbide liquidus 20 of the

iron-carbon-M system. However, because of the lesser amount of carbon, the proeutectic austenite liquidus 16 is reached before reaching the eutectic 12 and consequently the alloy forms proeutectic austenite before finally forming the eutectic chromium carbides (M_7C_3) and eutectic austenite.

The eutectic austenite and any proeutectic austenite may not be stable upon cooling to ambient and may transform to martensite, pearlite or combinations of martensite and pearlite. Heat treatment can be performed to form martensite that hardens the alloy so as to be more wear resistant. It is also possible to temper the alloy to convert the martensite to ferrite and carbide so as to be more machinable. In addition, it is also possible to heat treat the alloy to form soft pearlite for improving machinability and after machining the alloy can again be heat treated to produce martensite for greater abrasion resistance.

Figure 2 illustrates at 200 magnification one example of a microstructure of an alloy according to the present invention. This alloy by weight is composed of:

	2.8% Carbon
	16% Chromium
	6% Niobium
25	0.5% Molybdenum
	0.6% Nickel
	Balance Iron

This alloy includes primary MC niobium carbides, proeutectic austenite dendrites, eutectic M_7C_3 chromium carbides and eutectic austenite. The primary MC niobium carbides 30 are small compact particles dispersed in the proeutectic austenite dendrites 32. Eutectic M_7C_3 chromium carbides 34 (white) and eutectic austenite 36

(dark) form in alternate layers to make up the lacy-shaped constituent that surrounds the primary austenite dendrites. The nickel and molybdenum are in solid solution in the carbide and austenite constituents and
5 increase hardenability.

Figure 3 illustrates at 200 magnification another example of a microstructure of an alloy according to the present invention. This alloy by weight is composed of:

10	4.0% Carbon
	15% Chromium
	8.4% Vanadium
	1.1% Nickel
	0.6% Molybdenum
15	Balance Iron

This alloy includes primary MC vanadium carbides, eutectic M_7C_3 chromium carbides and eutectic austenite. The primary MC vanadium carbides 38 are the small compact particles dispersed throughout the alloy. The
20 eutectic M_7C_3 chromium carbides 40 (white) and eutectic austenite 42 (gray) form in alternate layers as the two lamellar constituents that make up the balance of the microstructure. The nickel and molybdenum are in solid solution in the carbide and austenite constituents and
25 increase hardenability.

Figure 4 illustrates at 200 magnification a further example of a microstructure of an alloy according to the present invention. This alloy is composed of:

30	2.8% Carbon
	15% Chromium
	3% Titanium
	0.5% Molybdenum
	0.6% Nickel
35	Balance Iron

This alloy includes primary MC titanium carbides, proeutectic austenite dendrites, eutectic M_7C_3 chromium carbides and eutectic austenite. The primary MC titanium carbides 44 are small compact particles dispersed in the proeutectic austenite dendrites 46. Eutectic M_7C_3 chromium carbides 48 (white) and eutectic austenite 50 (dark) form in alternate layers to make up the lacy-shaped constituent that surrounds the primary austenite dendrites. The nickel and molybdenum are in solid solution in the carbide and austenite constituents and increase hardenability.

Figure 5 illustrates at 200 magnification a further example of a microstructure of an alloy according to the present invention. This alloy by weight is composed of:

	3.8% Carbon
	14% Chromium
	6% Vanadium
	4.2% Niobium
20	1.0% Nickel
	0.5% Molybdenum
	Balance Iron

This alloy includes primary MC niobium and vanadium carbides, proeutectic austenite dendrites that have been partially converted to martensite, eutectic M_7C_3 chromium carbides and eutectic austenite that has been partially converted to martensite. The primary MC niobium and vanadium carbides 52 are compact and clustered particles dispersed throughout the alloy. The eutectic M_7C_3 chromium carbides 54 (white) and eutectic austenite 56 (dark) form in alternate layers as the two lamellar constituents that make up the balance of the microstructure. The nickel and molybdenum are in solid

solution in the carbide and austenite constituents and increase hardenability.

5 All of the examples of the alloy thus have a relatively high percentage of chromium, about 15% or more, as well as having an appropriate amount of carbon such that the eutectic 12 (Figure 1) of the iron-carbon-M system is below the hypoeutectic austenite liquidus 16 of the iron-carbon-chromium system such that there is no formation of eutectic carbides of vanadium, niobium or
10 titanium as previously mentioned.

While the best modes for practicing the invention have been described in detail, those familiar with the art to which this invention relates will
15 recognize various alternative designs and embodiments for practicing the invention as defined by the following claims.